APPLICATION NOTE

Megger.

THE IMPORTANCE OF THE GUARD TERMINAL IN INSULATION TESTING

Insulation resistance measurement is one of the most widely used tests for power assets but, to achieve dependable results, it's universally accepted that it's essential to use a test set with a guard terminal. We look at why this is and examine the frequently neglected issue of guard terminal performance.

When making an insulation resistance test, a known high DC voltage is applied to the asset under test and the resulting current flow is measured. Using Ohm's law, the current value, which is usually very small, is converted into an insulation resistance value. Comparing this insulation resistance value with predetermined pass/fail criteria helps in determining the safety and quality of the asset's insulation system. In addition, if insulation resistance tests are carried out periodically on an asset, the results can be trended to reveal changes, which can help to detect degradation of the insulation system and predict the remaining lifespan of the asset.

Every part of the electrical power infrastructure, from the point of generation through transmission and distribution to eventual use by the consumer, relies on effective insulation. Continuing availability of the electricity network is of paramount importance, so it is clearly essential that when we measure insulation resistance values, we can rely on the results we obtain.

Let's consider for a moment what happens if we get it wrong and the measurements are incorrect. If the results we are relying on are lower than the true insulation resistance values, assets may be prematurely withdrawn from service, maintenance teams may carry out needless replacement of costly assets and part of the network may be taken out of service to allow this unnecessary work to be carried out. All of this leads to higher maintenance costs and lower network availability, higher prices for the consumer, and potentially less profit for the utilities.

To eliminate these problems, we need to use insulation resistance instruments that consistently provide accurate and reliable readings. To understand what this means in practice, we need to look more closely at the very small currents an insulation resistance tester measures.
Once transient currents such as capacitive charging current and absorption (or polarization) current have fallen to negligible values in the asset under test, we are left with a small steady-state current known as the conduction or leakage current. This is made up of two components:

- Leakage current **through** the insulation material
- Leakage current **over the surface** of the insulation

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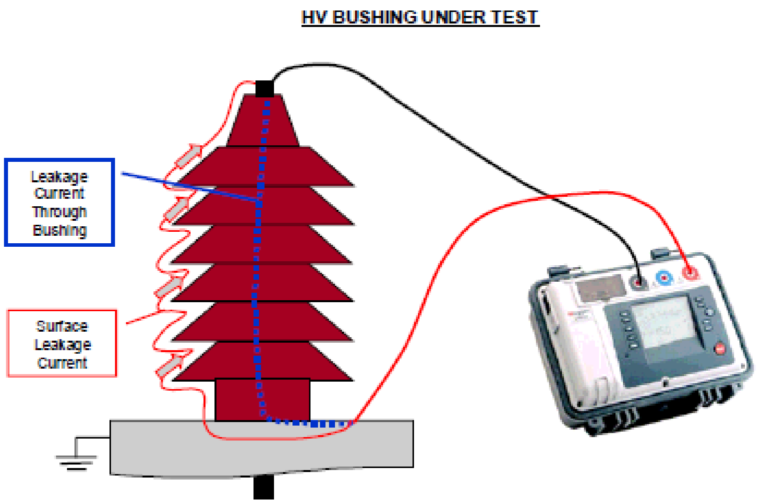
Ultimately, we use the leakage current through the insulator as the basis for our decisions about the asset's continuing usefulness. But in certain asset types, the leakage current over the surface of the insulator can dominate the measurements to such an extent that the measured insulation resistance values cannot be relied upon.

Large cables, windings, power transformers, electrical bushings and other assets that have large surface areas can become contaminated by airborne dirt or even a thin film of moisture. These conditions tend to lead to significant surface leakage current which can seriously affect the measurement of the true insulation leakage current.

In the following diagram of a contaminated bushing, the insulation leakage current through the bushing insulating material is shown in blue and the surface leakage current is shown in red. These two currents combine at the top of the bushing before returning to the instrument via the negative (black) lead. The instrument measures the combined current and will therefore provide a falsely low insulation resistance value.



Measured current = surface leakage current + insulation leakage current

To avoid this problem, we need to remove the surface leakage current component from our measurements, especially when we are measuring an asset with an insulation resistance of 100 MΩ or more at voltages of 1000 V and above. This is where the guard terminal comes into play.

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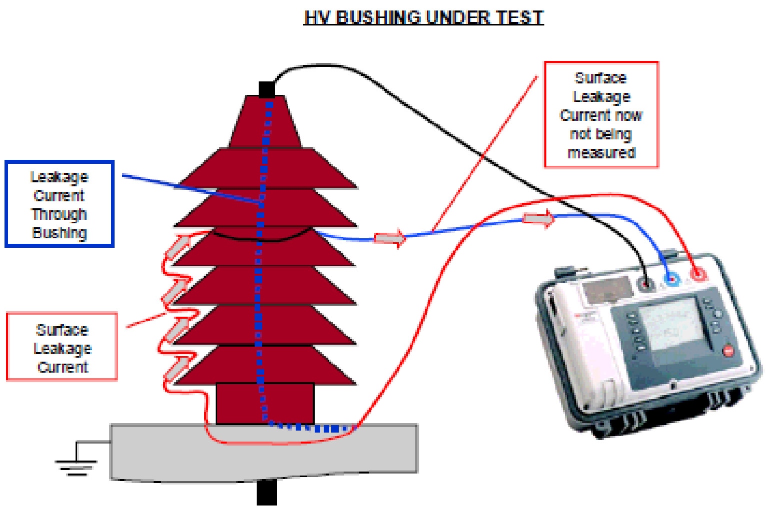
The guard terminal is a third connection that is made to the asset under test. This connection provides a return path for the surface leakage current that, as we have seen, can otherwise lead to a substantial error in the insulation resistance measurement.

Once again taking an HV bushing as our example, the diagram below shows how the surface leakage current passing over the outside of the Insulator is "guarded out" by wrapping a conductive band around the mid to upper part of the bushing. This takes the surface leakage current out of play and allows the test instrument to measure just the true insulation leakage current.



Measured current = insulation leakage current only. Surface leakage current is "guarded out".

One of the benefits of the guard terminal is that it can be used as a rapid first-line diagnostic tool. Two easy tests can quickly determine whether an asset's insulation system is truly degrading or if it is simply contaminated with dirt, and therefore in need of proper cleaning. The first test is carried out using the guard terminal and the second test without using it. If the two measured insulation resistance values differ dramatically, then it's clear that contamination is the underlying issue, causing the instrument, when used without the guard terminal, to show lower insulation resistance values than expected.

The guard terminal is also important when insulation resistance measurements are made periodically on an asset so that the results can be trended. There are many variables that can influence an asset's measured insulation resistance value, including for example, electrical noise and temperature. So, when trending insulation resistance values over the asset's lifecycle, the use of the guard terminal for each and every measurement is a necessity. This is because it removes the additional variable of surface leakage which itself changes over time as a result of contamination and differing levels of relative humidity at the time of testing.

We've seen that a guard terminal is an essential feature of a high-voltage insulation resistance tester if dependable results are to be obtained. But it's important to note that not all guard terminals are the same – in fact guard terminal performance differs greatly between instruments from different manufacturers.

Megger provides a guard terminal on a number of its products, starting with the handheld MIT2500, which can test at up to 2.5 kV, right up to the flagship S1-1568 which tests at up to 15 kV. The company fully declares the performance of its guard terminals, stating the accuracy and providing typical insulation resistance and parallel surface resistance values. Unlike some other manufacturers, Megger declares the accuracy across the instrument's full output voltage range, rather than at a specific output voltage that may not be typical of normal usage.

Guard terminal circuitry needs careful design to ensure low input impedance, which is essential for accuracy, while at the same time achieving a high CAT safety rating in line with IEC 61010, so that users remain safe in the event of transients or induced voltages appearing in the circuit under test. Both of these features are important but providing them means implementing higher cost instrument circuitry that can respond instantly to block transients that might endanger both the user and the instrument.

Some test instrument suppliers have attempted to keep costs down by using high resistor values in the guard terminal circuitry as a way of achieving high CAT safety ratings for their instruments. Unfortunately, this increases the input impedance of the guard terminal and degrades its performance.

These low-cost components also add unnecessary load on the instrument and, as a result, it is unable to maintain the specified test voltage, especially for lower values of insulation resistance. The output voltage simply collapses, making the test out of specification which automatically invalidates any results that might be obtained.

Further, where high-value resistors have been used to boost guard terminal CAT ratings in the data sheet, a careful examination of the user guide will sometimes reveal that only the guard terminal is CAT rated – the positive and negative test terminals are not! The guard terminal is probably the most unlikely place for transients to be seen, so this practice is definitely evidence of poor design. As you would expect, all the terminals of Megger HV insulation testers are CAT rated.

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Selecting the right insulation resistance tester can be difficult. Given the wealth of products available today, looking through data sheets, navigating through some of the pitfalls highlighted in this article and trying to determine what to buy is a time-consuming challenge. With this in mind, Megger has produced an invaluable aid to help you compare your shortlisted products. The **CB101G** is a simple and safe tool that contains a number of high-power resistors rated for use up to 5 kV. This tool can be used to quickly and positively confirm the performance – or lack of performance! – of the guard terminal on almost any insulation resistance tester.

The high-performance guard terminals on Megger's insulation resistance testers ensure that these instruments deliver accurate, verifiable insulation resistance values that can be relied upon and used to make a correct and informed decision about an asset's true insulation condition.

Effective predictive maintenance relies on trending dependable test results to provide an early indication of impending failure. The use of a high-performance guard terminal can, therefore, reduce the risk of premature asset replacement and ensure maximum service life. Maintenance teams can perform the correct activity at the most appropriate times, keeping costs to a minimum and maximising the availability of the network.

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